Anterior cranial-base time-related changes: A systematic review

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Introduction: The anterior cranial base has long been considered a stable reference structure for superimposing radiographs. However, some studies have questioned its stability. Therefore, the purposes of this systematic review were to give an overview of the studies evaluating growth and development of the anterior cranial base, assess their methodologic quality, and evaluate their validity and accuracy. **Methods:** Medline, Embase, and Google Scholar were searched without limitations up to June 2013. Additionally, the bibliographies of the finally selected articles were hand searched to identify any relevant publications that were not identified before. The lowest levels of evidence accepted for inclusion were cohort and cross-sectional studies. **Results:** A total of 11 articles met all inclusion criteria. They were published between 1955 and 2009. The sample sizes of these studies ranged from 28 to 464 subjects. Their methodologic quality ranged from moderate to low. **Conclusions:** Sella turcica remodels backward and downward, and nasion moves forward because of the increase in size of the frontal sinus. These events lead to a continuous increase in the length of the cranial base until adulthood. The presphenoid and cribriform plate regions can be considered stable after age 7, making them the best cranial-base superimposition areas. (Am J Orthod Dentofacial Orthop 2014;146:21-32)

An understanding of craniofacial growth is crucial for improved diagnosis, treatment planning, outcome evaluation, and long-term stability.[1] Historically, orthodontists have used the cranial-base structures as reference structures to evaluate craniofacial growth. The anterior cranial base is considered to have completed its most significant growth before other facial skeletal structures.[2] Hence, the anterior cranial base has long been considered a stable craniofacial structure to be used for cephalometric superimpositions during the usual orthodontic treatment age range.[1,3]

The cranial base is initially formed in cartilage, with ossification centers appearing early in embryonic life; with time, they progressively replace the cartilage with bone. However, some cartilaginous growth centers called synchondroses remain active between ossified areas and mature at different times of life. Bastir et al[2] stated that the earliest structure to mature in shape and size in the skull is the midline cranial base (at 7.7 years of age). However, this has been recently questioned. Malta et al[4] found that the anterior cranial base is not stable in size and grows during all pubertal phases (CS1 to CS6 of the cervical maturation stages). They reported that the anterior cranial-base length (sella to nasion) increases until early adulthood.

Various methods have been described to evaluate craniofacial growth. Craniometry was the first measurement approach for evaluating growth, used since the 15th century.[5] The advantage of this technique is that precise measurements can be made on dry skulls, but the limitation is that all the growth data are cross-sectional.[1] Anthropometry was then used as the gold standard because it can follow growth directly on each subject. Despite its accuracy, however, obtaining growth measurements through direct measurements is difficult because it is time-consuming and requires patient compliance to remain still for a long time.[6] Early in the 1900s, serial photographs started to be used to assess facial growth. However, they only show trends of growth rate and direction, and they lack accuracy for some measurements. Later during the last century, the metallic implant radiography method provided new information about the growth pattern, but the disadvantage was that

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Table I. Search strategy for MEDLINE via OVIDSP (1950 to the present)

Search group	*Medical subject heading (MeSH) or key word*
1	Maxillofacial development/OR growth/
2	*skull/or ethmoid bone/or exp facial bones/or exp skull base/or expsphenoid bone/OR exp *mandible/or *maxilla/OR cranial base.mp
3	Cephalometry/is, mt, st, td, ut [Instrumentation, Methods, Standards, Trends, Utilization] OR exp Cone-Beam Computed Tomography/is, mt, st, td, ut [Instrumentation, Methods, Standards, Trends, Utilization] OR exp Imaging, Three-Dimensional/is, mt, st, td, ut [Instrumentation, Methods, Standards, Trends, Utilization] OR superimpos*.mp. [mp = title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept, rare disease supplementary concept, unique identifier] OR exp Methods/is, mt, st, ut [Instrumentation, Methods, Standards, Utilization]
4	1 AND 2 AND 3

Limitation: human subjects.

it required placing implants on the subjects; this is no longer considered ethical.[7] Vital staining methods were also used in experimental animals to evaluate growth, but because of their invasiveness, they have only been used in humans to diagnose areas of rapid bone remodeling.[8]

Soon after the invention of the technique of lateral cephalometric x-rays in the 1930s, this became the most common way to evaluate facial growth among orthodontists. The disadvantage of this imaging technique is that 3-dimensional (3D) structures are represented in 2 dimensions. Several morphometric tools such as thin-plate spline analysis, elliptic Fourier analysis, finite element analysis, and tensor and shape coordinate analysis have been applied to 2-dimensional cephalometric comparisons. These methods have allowed for visualization of morphologic changes without the need for typical reference structures.[9]

In the late 1990s, the 3D digital imaging technique was introduced. This provides comprehensive information regarding anatomic relationships and eliminates some limitations encountered when studying 2-dimensional images.[10] Laser surface scanning and 3D stereophotogrammetry methods are also the results of recent technologic advancements in 3D imaging; however, they usually apply only in 3D facial surface scanning.[6]

As can be perceived from this introduction, multiple methods have been used through the years to analyze craniofacial changes. Even though the anterior cranial base has been considered stable and used as the reference structure for superimposing radiographs, this has recently been questioned. Because the use of the anterior cranial base as a reference structure has paramount importance in orthodontics, it would be extremely useful to comprehensively analyze the evidence to question its stability. Therefore, the purposes of this systematic review were to give an overview of the studies evaluating growth and development of the anterior cranial base, assess their methodologic quality, and evaluate their validity and accuracy.

MATERIAL AND METHODS

This systematic review was reported using the PRISMA checklist as a template.[11]

No review protocol or systematic review registration was considered.

In phase 1, only the titles and abstracts collected from the electronic database searches were considered. Articles that assessed craniofacial growth or analyzed treatment outcome but had a control group without treatment were considered. No language limitations were applied. Studies assessing fetal growth with photographs only or assessing frontal x-rays only were excluded. Animal studies were also excluded.

In phase 2, in which copies of full articles were reviewed from those selected in phase 1, some articles were excluded if they did not specifically evaluate cranial-base growth, or if they were reviews or case reports. Ultimately, all included studies must have assessed the growth and development of the anterior cranial-base structures.

With the assistance of a senior health-sciences librarian, we conducted a computerized systematic search in 2 electronic databases. Medline (via OvidSP) and Embase (via OvidSP) were searched from their earliest records until June 15, 2013. The bibliographies of the selected articles were also hand searched for additional relevant studies that might have been missed in the electronic searches. In addition, a limited gray literature search was conducted with Google Scholar.

Specific medical subject headings and keywords were used in the search strategy of Medline (Table I). The search strategy for the Embase database was derived from the former and was modified appropriately (Appendix 1).

In both steps of the review process, 2 reviewers (M.A. and C.P.L.) independently reviewed titles and abstracts according to the inclusion and exclusion criteria noted above. Disagreements between the 2 reviewers were resolved through discussion until consensus was achieved.